(54) Title: AUDIO REPRODUCTION APPARATUS, METHOD, COMPUTER PROGRAM PRODUCT

(57) Abstract: The audio reproduction apparatus (100) for sports training purposes comprises a tempo derivation unit (103) for deriving a selected tempo (T) on the basis of a data signal (dl, d2, d3) e.g. from a sports measurement device such as a heart rate meter; and an audio conditioning unit (104) arranged to deliver based on the input audio signal the output audio signal, with a tempo within a predefined accepted deviation from the selected tempo (T), whereby the audio conditioning unit (104) comprises a tempo calculation unit (106) arranged to calculate an input tempo (TI) of the input audio signal, and the audio conditioning unit (104) is arranged to deliver the output signal in dependence of the input tempo (TI).

GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD,*

SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

1

Audio reproduction apparatus, method, computer program product

The invention relates to an audio reproduction apparatus suitable for use during sports training comprising:
- an input for inputting an input audio signal;
- an output for outputting an output audio signal;
5 - a user behavior identification unit capable of providing a data output; and
- an audio conditioning unit for conditioning the output audio signal dependent on the data output from the user behavior identification unit.

The invention further relates to a method for delivering an output audio signal with an output tempo within a predefined deviation from a selected tempo comprising:
10 - inputting an input audio signal;
- deriving a selected tempo on the basis of a data signal; and
- delivering based on the input audio signal an output audio signal, with an output tempo within a predefined deviation from the selected tempo.

The invention further relates to a computer program product comprising
15 commands enabling a processor to execute the method.

A variant of such an apparatus is known from US2001/0035087-A. The apparatus contains an embodiment of a user behavior identification unit being a gesture input
20 and interpretation module. In the known apparatus, the gesture input and interpretation module typically analyzes a trajectory of e.g. a mouse movement, the mouse being moved by a user. The known apparatus also contains an audio conditioning unit, called a playback decision module, for selecting from a music database pieces of music with a particular emotional character corresponding to the gesture made. E.g. moving the mouse up and down
25 in an excited way may result in the selection of a piece of music containing drum sounds. One of the available emotional characters that can be used for selection mentioned in the cited document is a selected tempo of the pieces of music.

It is a disadvantage of the known apparatus that it is not flexible. Pieces of music have to be tagged in advance by a person, the tag describing the emotional character of

the piece of music, which severely limits the number of available pieces of music which can be used with the known apparatus. If the gestures are used to compose a composition of music pieces, it will not sound very beautiful if there is only a limited set to choose from. Furthermore a tag typically specifies a tempo in a vague manner, such as: the tempo is "fast",

5   "very fast", "slow" or "excited". An additional problem of the known apparatus is that each piece of music has a fixed tempo, as noted in its tag. Attempting to solve this problem, the known document describes another embodiment of the known apparatus which contains a musical instrument digital interface (MIDI) coder. A MIDI signal of a known tempo can be recoded to a new tempo. However the fact that this only applies to electronic music is again a

10   flexibility limitation.

        It is a first object of the invention to provide an apparatus of the kind mentioned in the opening paragraph which is relatively flexible as to the types of input audio

15   signal, e.g. music, that can be used as input to deliver an output audio signal of substantially the selected tempo.

        It is a second object to provide a method of the kind mentioned in the opening paragraph which is relatively flexible as to the types of input audio signal, e.g. music, that can be used as input to deliver an output audio signal of substantially the selected tempo.

20   The first object is realized in that

-       the user behavior identification unit is a tempo derivation unit for deriving the data output being a selected tempo, on the basis of a data signal;

-       the audio conditioning unit comprises a tempo calculation unit arranged to calculate an input tempo of the input audio signal; and

25   -   the audio conditioning unit is arranged to deliver the output audio signal with an output tempo within a predefined deviation from the selected tempo, the output signal depending on the input tempo.

        When analyzing user gestures, an excitedness of up and down movement of a mouse can be used for the derivation of an approximate indication of the selected tempo.

30   However the selected tempo can be derived much more accurately on the basis of a data signal from e.g. a pace meter on a running shoe. Such tempo measuring devices allow new applications, e.g. in sports. It is known that runners tend to run with a pace corresponding to the tempo of music playing, so an apparatus providing music of the correct tempo to the runner can facilitate his training. In general, in the apparatus according to the invention, the

selected tempo is selected by a person doing sports or being engaged in a similar activity, such as a soldier on a march, according to his requirements.

The tempo calculation unit is comprised as a key feature of the apparatus according to the invention, to enable the apparatus to determine the input tempo of most types of input audio signal, e.g. real music from a radio or MP3 decoded audio, electronic music, or if required even speech.

An embodiment of the audio reproduction apparatus according to the invention comprises selection means capable of selecting as the input audio signal a piece of audio from an audio source, and the audio conditioning unit is arranged to deliver the output audio signal based on the input audio signal if a condition is met, being: the absolute difference between the selected tempo and the input tempo is below the predefined deviation. The selection means are arranged to search the audio source and select from it different pieces of audio or music as the input audio signal, until a piece of audio or music is found of roughly the selected tempo. Once the condition is met, in a simple variant of the embodiment, the conditioning unit is arranged to send the input audio signal to the output as the output audio signal. Since in this case the output signal is the input signal, the absolute difference condition on the output tempo can be formulated as an absolute difference condition on the input tempo. An advantageous instance of the audio source is a memory containing MP3 encoded audio. Nowadays a typical memory, which may be included in the audio reproduction apparatus, can store hundreds of pieces of music, so a nice training composition can be constructed from them for whichever training session. Another variant of the selection means is arranged to search radio channels to find the correct music.

In an advanced variant of the embodiment, the audio conditioning unit further comprises an audio processing unit, arranged to derive, based upon the input audio signal, the output signal with an output tempo closer to the selected tempo than the input tempo. The audio processing unit may be arranged to apply a tempo adjustment --realized in software or hardware- which offers the option of finetuning or in general adjusting an incorrect tempo of a selected input audio signal from the audio source. This is interesting in case there is not much music available in the audio source with substantially the selected tempo. The audio-processing unit may also be arranged to compensate for tempo variations within a selected piece of music. A simple algorithm for changing the tempo constructs the output audio signal by adding samples of the input signal to a substantially zero output signal, at time instances determined by the selected tempo, and applying an interpolation filter. This algorithm results in a difference of pitch of the input and the output audio signal, which may for large tempo

adjustments lead to a cartoon-like reproduction of singing voices, and off key music. Pitch preserving tempo-changing algorithms can be applied in a high quality variant of the advanced variant, as described below for a different embodiment.

An alternative embodiment of the audio reproduction apparatus according to
5   the invention comprises an audio processing unit, arranged to construct, based on the input audio signal, the output audio signal with an output tempo closer to the selected tempo than the input tempo, and with an output pitch substantially equal to an input pitch of the input signal. By incorporating such an audio processing unit, it is not necessary to comprise selection means, since each input audio signal can be processed to obtain an output audio
10   signal of roughly the selected tempo. Of course selection means may be present to select the input audio based on different criteria, e.g. by a user.

In a specific variant of the alternative embodiment, the audio conditioning unit comprises an audio processing unit, arranged to construct, based on the input audio signal, the output audio signal with an output tempo closer to the selected tempo than the input
15   tempo, starting from a substantially zero value output audio signal, by adding input audio segments of consecutive samples of the input audio signal to the output audio signal, at output time instances determined by the ratio between the selected tempo and the input tempo, the input audio segments being selected on the basis of a predefined audio segment similarity criterion, and the samples in the segments being weighed by a predefined weighing
20   function before being added to the output audio signal. The idea behind this algorithm is that pitch corresponds to a short time scale variation of the audio signal, whereas tempo manifests itself on a longer time scale, e.g. a quarter of a second. On the short time scale successive segments of the audio signal are relatively similar -e.g. for a particular audio signal they are similar in each 400th of a second interval- , a fact of nature which a human ear exploits to
25   determine the pitch. By means of the predefined audio segment similarity criterion, the similar segments in the input audio signal are extracted. They are added to the output audio signal at the required temporal positions. E.g. if the output tempo is half as fast as the input tempo, the input audio segments are placed in the output audio signal twice as far apart in time as in the input audio signal. The gaps in between are filled by copying the input audio
30   segments to the output audio signal again, or by adding calculated segments similar to the local input audio segments. Since the neighboring segments are similar, copying more or less of these similar segments to the output audio signal hardly changes the perceptual characteristics of the output audio signal as compared to the input audio signal, apart from the

tempo or duration. The weighing is included to make the output audio signal smoother, leading to a reduction in the amount of perceptible artifact.

It is advantageous if the audio processing unit comprises a local tempo variation unit, arranged to apply between a first input audio segment and a first output audio segment, based on the first input audio segment, a first tempo adjustment with a first tempo change, and to apply between a second input audio segment and a second output audio segment, based on the second input audio segment, a second tempo adjustment with a second tempo change, whereby the first tempo change is different from the second tempo change. E.g., by slowing the duration of some notes, e.g. played on a trumpet, more than the duration of notes in their the temporal environment, an additional suggestion of slowness can be simulated, which is advantageous for obtaining relaxing music.

The audio reproduction apparatus may further comprise a workout scheme specification unit, arranged to allow a specification of a series of consecutive selected tempos. This enables a user to specify an entire workout scheme, only as a set of tempos, so that the actual music played can still be varied according to his desire. The specification may be done during the exercise or at home on a p.c. and downloaded to the apparatus. Other people than the user may also contribute to the specification.

The second object is realized in that the method is characterized in that an input tempo of the input audio signal is calculated, and the output signal is delivered in dependence of the input tempo.

These and other aspects of the audio reproduction apparatus according to the invention will be apparent from and elucidated with reference to the implementations and embodiments described hereinafter, and with reference to the accompanying drawings, which serve merely as non-limiting illustrations.

In the drawings :

Fig. 1 schematically shows the audio reproduction apparatus according to the invention;

Fig. 2 schematically shows an embodiment of an audio-conditioning unit;

Fig. 3 introduces the nomenclature used for characterizing the meter of a piece of music;

Fig. 4a and 4b schematically shows an example embodiment of a tempo calculation unit;

Fig. 5 schematically shows the signal processing of a particular pitch preserving tempo changing algorithm;   and

Fig. 6a and 6b shows two example workout specifications;

In these Figures elements drawn dashed are optional, depending on the desired

5   embodiment.

Fig. 1 shows an audio reproduction apparatus 100 with an input 101 for inputting an input audio signal i, and an output 102 for outputting an output audio signal o,

10   typically derived from the input audio signal. The audio reproduction apparatus is intended for sports training or similar activity and comprises a tempo derivation unit 103 for deriving a selected tempo T on the basis of a data signal d1, d2, d3. The audio reproduction apparatus 100 may e.g. be portable, connectable to a wearable sports measurement device or may be attached to a fitness apparatus. E.g. a runner may wear a sports shoe containing a pace meter

15   134, which measures the runner's pace i.e. how many steps are taken each second, e.g. based on an acceleration sensor or a deformation sensor. E.g., based on an acceleration timeline the acceleration sensor may transmit a number representing the pace as a first data signal d1 to the tempo derivation unit 103. Alternatively, the tempo derivation unit 103 may be arranged to perform the computation of the pace based on an incoming first data signal d1 comprising

20   the acceleration timeline. The tempo derivation unit 103 may be arranged to calculate a selected tempo T based on the measured runner's pace, according to a selection strategy. E.g. the selected tempo can be set equal to or within a predefined interval of the pace. The runner can then listen to music of an output tempo substantially equal to his pace, which makes his running easier. The pace can e.g. be measured at a number of time instances and an average

25   pace can be determined as a baseline. If the runner then runs uphill for a short time, the selected tempo and hence the output tempo is not adjusted, so that the music motivates him to keep running at the same pace.

In an alternative tempo selection strategy, a desired training level can be set. E.g. a heart rate meter 132 on a step machine in a fitness center may be transmitting the heart

30   rate of a user exercising to the tempo derivation unit 103. A desired heart rate is set on the step machine. As long as the actual heart rate of the user is below the desired heart rate, for a predefined interval of time to take into account adaptations in the heart rate of the user to increased exercise load conditions, fast music is played. The user can then fasten his step according to the output tempo of the music. The desired heart rate may come in as a second

7

data signal d2 together with the actual heart rate of a user at a time instance, or they may be two different data signals into the tempo derivation unit 103. The user can also specify a selected tempo T by means of a user input 130 as a third data signal d3. Other measurement devices characterizing sports activities may also be used, such as e.g. an oxymeter, a

5   breathing analyser, or the onboard computer of a training apparatus which e.g. sends as a data signal the speed of a rolling carpet.

A workout scheme specification unit 180 may also be present, which is arranged to allow a user to specify a series of consecutive selected tempo's T according to his desire, formulating an exercise schedule for successive time intervals. E.g. the user wants to

10   start training with slow warm up music, then likes to continue with ten minutes strenuous exercise requiring music of a fast tempo, and ending with slow music for cool down and relaxation purposes. If synchronization means 182 are connected to the workout scheme specification unit 180, e.g. a wired or wireless connection to a master server or another similar audio reproduction apparatus, group training or training games in which a first user

15   selects the selected tempo for a second user become possible. E.g. the selection means may comprise a connection to an Internet server on which a personal trainer has stored a daily training profile.

Given the selected tempo T, an audio conditioning unit 104 is arranged to deliver based on the input audio signal i the output audio signal o, with an output tempo TO

20   within a predefined deviation d from the selected tempo T. The input audio signal i originates from an audio source of audio pieces, which may be e.g. a radio receiver, but advantageously may be a database of music pieces in the audio reproduction apparatus, such as a memory containing compressed audio files, or a CD reader. A tempo calculation unit 106 is arranged to calculate an input tempo TI of the input audio signal i. If a condition is met, being the

25   absolute difference between the selected tempo T and the input tempo TI is below the predefined deviation d, the audio conditioning unit 104 may be configured to transmit the input signal i as the output signal o to the output 102. In a simple realization, the tempo calculation unit 106 is arranged to send a control signal over a first control connection 154 to a switch 152. If the input audio signal is of roughly the desired selected tempo the switch 152

30   is closed and otherwise it is open. The output 102 may be connected to a sound production means 122, such as a loudspeaker, or advantageously headphones.

If the absolute difference between the selected tempo T and the input tempo TI is above the predefined deviation d, the input audio signal does not conform to the user's likings as expressed in the selected tempo T, and some action has to be taken by the audio

conditioning unit 104. Otherwise, in the simple realization the user hears no output audio as long as the condition is not met, since the switch 152 is open. The switch could be forced closed, but then music of the wrong output tempo is outputted. An embodiment of the audio reproduction apparatus 100 comprises selection means 150 which is arranged to select

5   individual pieces audio from the audio source 120. The selection means 150 may e.g. be realized as a data connection or bus to the audio source 120, transmitting a "next song" commando or an index of a song, in case the input tempo TI is incorrect. The selection process continues until an audio piece of substantially the selected tempo is found. Instead of calculating the input tempo TI of a piece of audio on the fly, a memory 160 (see Fig. 2) may

10   be comprised, which contains a table of indices of audio pieces from the audio database and corresponding input tempo's TI, which table may typically be enlarged each time a piece of audio is loaded as an input signal and its tempo is calculated by the tempo calculation unit 106. The advantage of such a table is that an audio piece of substantially the correct input tempo TI can immediately be selected, instead of having to go through and analyze all the

15   audio pieces sequentially each time. The audio source 120 may comprise a set of versions of the same song or audio piece with different tempos. This is interesting for a variant of the audio reproduction apparatus 100, which is only arranged to select input audio of substantially the desired tempo and is not arranged to change the tempo of a selected piece of audio. A song may then be processed to obtain 10 versions of different tempo –e.g. on a p.c.-,

20   which are then downloaded into the audio source 120 of e.g. a portable solid state MP3 or CD player.

While the selection means are searching for the correct song, and the condition is not met, a fallback audio setting unit 190 detecting the state of the switch 152 by means of detecting means 194, may furnish the output audio signal o, by temporarily supplying e.g. a

25   default audio piece or the previous audio piece. The fallback audio setting unit 190 may comprise an artificial audio generator 192 arranged to temporarily create an artificial output audio signal o, such as a sequence of audio segments containing a drum beat, or a sequence of electronic beeps.

Another embodiment may additionally or alternatively comprise an audio

30   processing unit 108, arranged to construct the output audio signal o with an output tempo TO being roughly the selected tempo T, i.e. within the deviation d of the selected tempo T, on the basis of the input signal i. Like all the functional components of the audio reproduction apparatus it may be realized as a hardware circuit or as a method running as software on a processor. A first possible way to derive an output audio signal o similar to the input audio

signal i but of changed tempo, samples the input signal, places the samples in the output
signal at a different intersample distance, and interpolates and/or filters. In a variant, a
number of successive samples of the input audio signal is used to determine an output audio
sample, e.g. by means of model prediction. Those algorithms in general introduce a

5   perceptible change in pitch. Hence pitch-preserving tempo changing algorithms may also be
employed by the audio-processing unit 108, such as the one described with the aid of Fig. 5.
In order to realize the tempo adjustment, the audio processing unit 108 may typically need
the input tempo TI and the selected tempo T, or their ratio, which can be sent over a tempo
connection 140 as a signal, coded number or any equivalent well known from prior art.

10   Tempo adjustment between the input audio signal and the output audio signal may occur
without selection of an input audio signal with a particular tempo, hence e.g. with a fixed
input audio signal, or in combination with input audio signal selection e.g. to correct for
small deviations of the input tempo TI from the selected tempo T for the output audio signal
o. Note that the value of the predefined deviation d for selection may be larger than for tempo

15   adjustment. In the first case it limits the number of songs that can be chosen from the audio
database, whereas in the second case it is a tolerance on the tempo adjustment accuracy.

        Fig. 2 schematically shows an embodiment of an audio-conditioning unit 104,
in which the dashed components may or may not be present in different configurations. An
input tempo calculation part 200 is drawn explicitly, which is arranged to apply e.g. the

20   algorithm explained by means of Fig. 4 to obtain the input tempo TI. A tempo comparator
202 is arranged to compare the calculated input tempo TI with the selected tempo T, and to
send a "next audio piece" signal over the selection means 150 if their absolute difference is
outside the predefined deviation d range, or by means of another tempo heuristic. Note that in
the drawn example of this embodiment the control signal of the first control connection 154

25   is also sent over the selection means 150 by the tempo comparator 202, but this may be
implemented with a different connection. The tempo comparator 202 may also be arranged to
send the input tempo TI and the selected tempo T over the tempo connection 140 in case
tempo adjustment by the audio processing unit is required as a result of a decision strategy
evaluation of the tempo comparator 202.

30   The audio-processing unit 210 may also comprise a local tempo variation unit
210, arranged to apply an alternative tempo adjustment for selected local time segments of
the output audio signal. In other words, the local tempo variation unit 210 is arranged to
apply between a first input audio segment and a first output audio segment, based on the first
input audio segment, a first tempo adjustment with a first tempo change, and to apply

between a second input audio segment and a second output audio segment, based on the
second input audio segment, a second tempo adjustment with a second tempo change,
whereby the first tempo change is different from the second tempo change. The adjustment
can also be made by re-processing certain parts of the output audio signal after a global

5   tempo adjustment. Especially for particular types of music, e.g. stretching single notes played
on e.g. a brass instrument in relation to the tempo of the rest of the song, can give the music
an even slower impression. This can be interesting during the relaxation part after training.
The local tempo variation unit 210 may perform automatic analysis to detect whether
particular instruments are present and in which time segments. It may also be arranged to

10   check for tags indicating that there are notes played by particular instruments at particular
times.

             Fig. 3 introduces the nomenclature used for characterizing the meter of a piece
of music. The meter is the hierarchy of time instances of particular events that describes a
particular piece of music. An event is e.g. the playing of a note or the stressing of a note. The

15   lowest level 306 is called the tatum, and coincides with the playing of single notes. Note
detection is starting point of a typical tempo calculator. The second level 304 is the level of
the beat or tactus. The number of beats per minutes is a measure of tempo. It is identified by
marking stress notes. Stress can be applied to a note e.g. by playing it louder or by a number
of other variations such as pitch variations, temporal shifts, etc. The highest level 302 shown

20   is the measure or bar.

             Fig. 4a schematically shows an example embodiment 400 of a tempo
calculation part 200. It proves favorable for accurate tempo calculation to split an audio
signal in multiple frequency bands by means of filters 402, 404, 406. These filters 402, 404,
406 are also designed to assure that the calculation occurs at the time scale of the tempo and

25   not the time scale of the pitch. The filtered signal is rectified by means of rectifiers 410, 412,
414 and the spatial difference signal is calculated by means of differentiators 420, 422, 424.
Further rectifiers 430, 432, 434 are present so that only the increasing slope differences are
retained. Correlators 440, 442, 444 are present to evaluate the periodicity of the rectifier
difference pulses. Analysis logic combines these periodicities, leading to a most probable

30   tatum prediction and looks for stress patterns in the tatum pattern, finally leading to the
tempo. A particular variant using oscillators for analyzing the periodicity is described in
"Eric D. Scheirer: Tempo and beat analysis of acoustic musical signals. Journal of the
acoustic Society of America 103, no. 1, 1998, pp. 588-601.".

Fig. 4b schematically shows what the audio signal looks like in a third processing branch 484, namely a filtered signal 460 behind a third filter 406 and a rectified difference signal 470 behind a sixth rectifier 434.

Fig. 5 schematically shows the signal processing of a particular pitch

5   preserving tempo changing algorithm, in a case in which the input tempo TI is twice the selected tempo T. The fundamental idea is that audio consists of repetitive patterns, hence if similar patterns are inserted in between, a longer stretch of audio is obtained without significant alteration of the other perceptible characteristics of the audio, and in particular the pitch. Similarly, if a shorter duration audio signal is required, some of the numerous similar

10   patterns can be dropped.

A first input segment 530 and a second input segment 532 are similar, as can be verified with a number of different similarity criteria. The output audio signal o can be constructed digitally by first setting all required samples equal to zero. The samples of the first input segment 530 at a first input time instance 510 are copied to a first output time

15   instance 520 to obtain a first output audio segment 540. The second input segment is drawn a little larger, symbolizing that the amplitude of an envelope of the input audio signal is slowly rising. Since for a tempo halving the amplitude variation of the output audio signal should be twice as slow, the second input segment 532 is copied to a third output time instance 524 to obtain a third output audio segment 544. There is no input data for a second output time

20   instance 522. But the output audio segment residing there should be similar to the first and the second output audio segment 540 resp. 544. Hence a second output audio segment 542 is constructed based on a weighed combination of samples from e.g. the first and second input audio segment 530 resp. 532, e.g. by means of equation 1:

$$y(k) = \frac{\sum_i w^2(k - iD + \Delta_i) x(k - iD + \Delta_i + \tau^{-1}(iD))}{\sum_i w^2(k - iD + \Delta_i)} \qquad [1]$$

25   In equation [1], the output audio signal y(k) is synthesized at all discrete times k, by overlap, at a discrete number of synthesis time instances -enumerated by i and positioned a temporal distance D apart- of audio segments excised from the input audio signal x. It is further assumed in equation [6] that both the excised and synthesized audio segments are weighted by the same weighing function w. $\tau^{-1}(iD)$ is the analysis time instance corresponding to a

30   synthesis time instance iD, where excision of a audio segment from the input audio signal has to occur. However, when adding an excised audio segment to a part of the output audio signal already synthesized, one has to be careful that an excised audio segment from the input audio

12

signal resembles closely an audio segment which is expected to follow the part of the output audio signal already synthesized. Therefore a small offset Δ_i is introduced, which allows for excision of an audio segment at a slightly different discrete time than $\tau^{-1}(iD)$.

Fig. 6a shows an example of a temporal workout specification 600 which can
5   be specified by a user and stored in memory in the workout scheme specification unit 180, if required together with additional data such as e.g. the name of the user, the date etc. The workout scheme specification unit 180 is then arranged to send a tempo to the audio conditioning unit 104 at a corresponding time instance. The temporal workout specification 600 comprises a consecutive set of specified time intervals, such as a first time interval 602
10   for warming up, and corresponding desired selected tempos, such as a first selected tempo 630. If the audio reproduction apparatus 100 is in a mode which adapts itself to the user's performance on short time scales rather than to use a fixed temporal workout specification, a user may want to deviate at certain instances of time from the desired selected tempo for the particular time interval without the audio reproduction apparatus 100 updating the current
15   selected tempo in the temporal workout specification 600. This is handy e.g. when he is running uphill for a short time. To achieve this, the workout scheme specification unit 180 may be arranged to allow the specification of tolerances, such as tolerance 620. The tolerances may be formulated e.g. as a lower and upper deviation from the desired selected tempo for the associated time interval and/or as a time interval during which the deviation of
20   the current selected tempo T corresponding to e.g. the runner's pace may deviate from the desired selected tempo for the current time interval in the temporal workout specification 600 by an arbitrary amount. This is handy e.g. when the user has to discontinue running because of a red traffic light.

Fig. 6b shows an alternative workout specification 650, which may be
25   advantageous in case the audio reproduction apparatus contains a display, a map of the neighborhood in memory, and localization means such as a global positioning system (GPS) unit. The user can then e.g. draw intervals such as a first spatial interval 670 on a representation of a first street 660, and a second spatial interval 672 on a representation of a second street 662, and specify corresponding tempos. As long as the user is running in the
30   first street, the selected tempo is equal to a first value, etc.

Under computer program product should be understood any physical realization of a collection of commands enabling a processor –generic or special purpose-, after a series of loading steps to get the commands into the processor, to execute any of the characteristic functions disclosed in the present invention. In particular the computer program

product may be realized as data on a carrier such as e.g. a disk or tape, data present in a memory, data traveling over a network connection –wired or wireless-, or program code on paper.

It should be noted that the above-mentioned embodiments illustrate rather than

5 limit the invention and that those skilled in the art are able to design alternatives, without departing from the scope of the claims. Apart from combinations of elements of the invention as combined in the claims, other combinations of the elements within the scope of the invention as perceived by one skilled in the art are covered by the invention. Any combination of elements can be realized in a single dedicated element. Any reference sign

10 between parentheses in the claim is not intended for limiting the claim. The word "comprising" does not exclude the presence of elements or aspects not listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

The invention can be implemented by means of hardware or by means of

15 software running on a computer, and previously stored on a data carrier or transmitted over a signal transmission system.

CLAIMS:

1.   An audio reproduction apparatus (100) suitable for use during sports training comprising:

-      an input (101) for inputting an input audio signal (i);
-      an output (102) for outputting an output audio signal (o);
-      a user behavior identification unit capable of providing a data output; and
-      an audio conditioning unit (104) for conditioning the output audio signal (o) dependent on the data output from the user behavior identification unit, characterized in that:
-      the user behavior identification unit is a tempo derivation unit (103) for deriving the data output being a selected tempo (T), on the basis of a data signal (d1, d2, d3);
-      the audio conditioning unit (104) comprises a tempo calculation unit (106) arranged to calculate an input tempo (TI) of the input audio signal (i); and
-      the audio conditioning unit (104) is arranged to deliver the output audio signal (o) with an output tempo (TO) within a predefined deviation (d) from the selected tempo (T), the output signal (o) depending on the input tempo (TI).

2.   An audio reproduction apparatus (100) as claimed in claim 1, comprising selection means (150) capable of selecting as the input audio signal (i) a piece of audio from an audio source (120), and wherein the audio conditioning unit (104) is arranged to deliver the output audio signal (o) based on the input audio signal (i) if a condition is met, being: the absolute difference between the selected tempo (T) and the input tempo (TI) is below the predefined deviation (d).

3.   An audio reproduction apparatus (100) as claimed in claim 2, wherein the audio conditioning unit (104) further comprises an audio processing unit (108), arranged to derive, based upon the input audio signal (i), the output signal (o) with an output tempo (TO) closer to the selected tempo (T) than the input tempo (TI).

15

4.   An audio reproduction apparatus (100) as claimed in claim 1, wherein the audio conditioning unit (104) comprises an audio processing unit (108), arranged to construct, based on the input audio signal (i), the output audio signal (o) with an output tempo (TO) closer to the selected tempo (T) than the input tempo (TI), and with an output

5   pitch substantially equal to an input pitch of the input signal (i).

5.   An audio reproduction apparatus (100) as claimed in claim 4, wherein the audio processing unit (108) is arranged to construct the output audio signal (o) by
          -        starting from a substantially zero value output audio signal (o), adding input

10   audio segments of consecutive samples of the input audio signal (i) to the output audio signal (o), at output time instances determined by the ratio between the selected tempo (T) and the input tempo (TI),
          -        the input audio segments being selected on the basis of a predefined audio segment similarity criterion,

15   -   and the samples in the segments being weighed by a predefined weighing function before being added to the output audio signal (o).

6.   An audio reproduction apparatus (100) as claimed in claim 3 or 4, wherein the audio processing unit (108) comprises a local tempo variation unit (210), arranged to apply

20   between a first input audio segment and a first output audio segment, based on the first input audio segment, a first tempo adjustment with a first tempo change, and to apply between a second input audio segment and a second output audio segment, based on the second input audio segment, a second tempo adjustment with a second tempo change, whereby the first tempo change is different from the second tempo change.

25

7.   An audio reproduction apparatus (100) as claimed in claim 1, comprising a workout scheme specification unit (180), arranged to allow a specification of a series of consecutive selected tempos (T).

30   8.   A method for delivering an output audio signal with an output tempo (TO) within a predefined deviation (d) from a selected tempo (T) comprising:
          -        inputting an input audio signal (i);
          -        deriving a selected tempo (T) on the basis of a data signal (d1, d2, d3); and

- delivering based on the input audio signal (i) an output audio signal (o), with an output tempo (TO) within a predefined deviation from the selected tempo (T), characterized in that an input tempo (TI) of the input audio signal (i) is calculated, and the output signal (o) is delivered in dependence of the input tempo (TI).

5

9. A computer program product comprising commands enabling a processor to execute the method of claim 8.
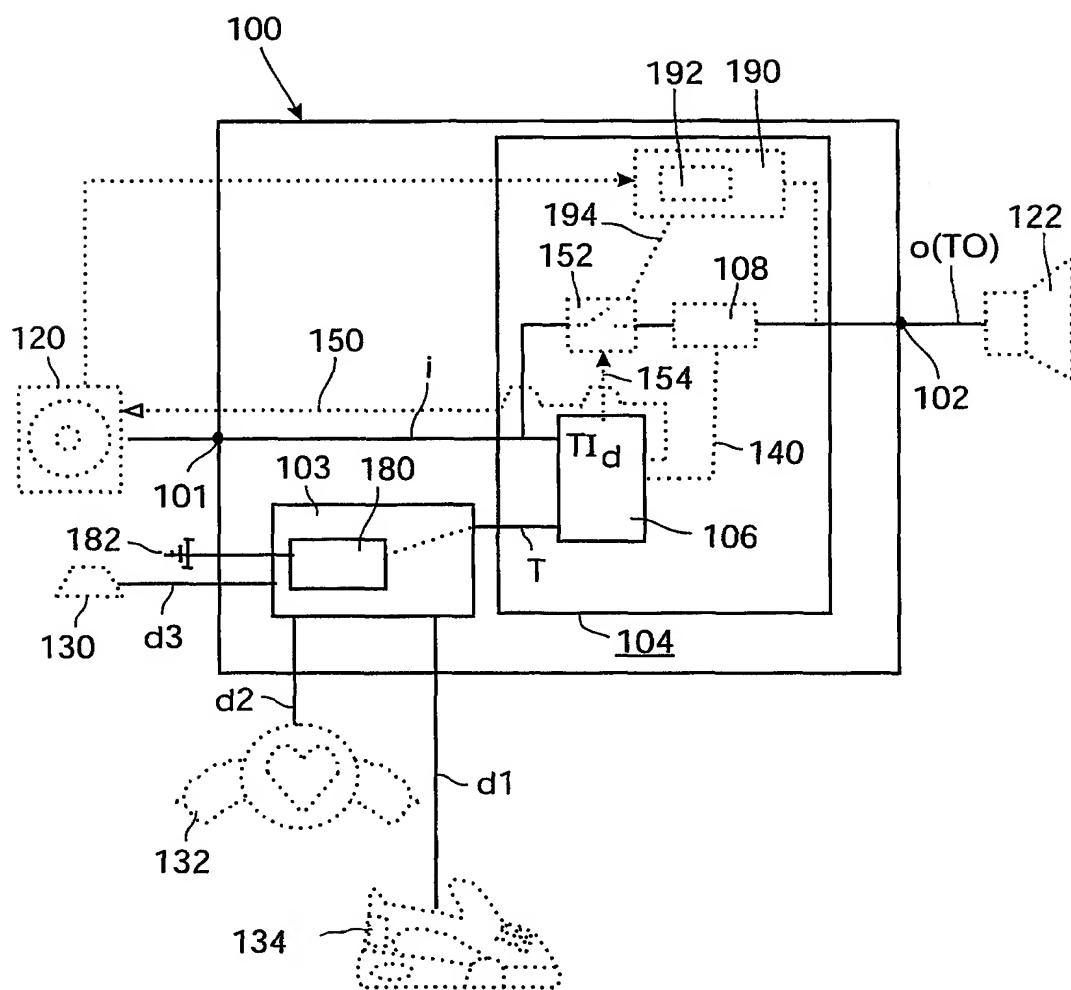
FIG.1
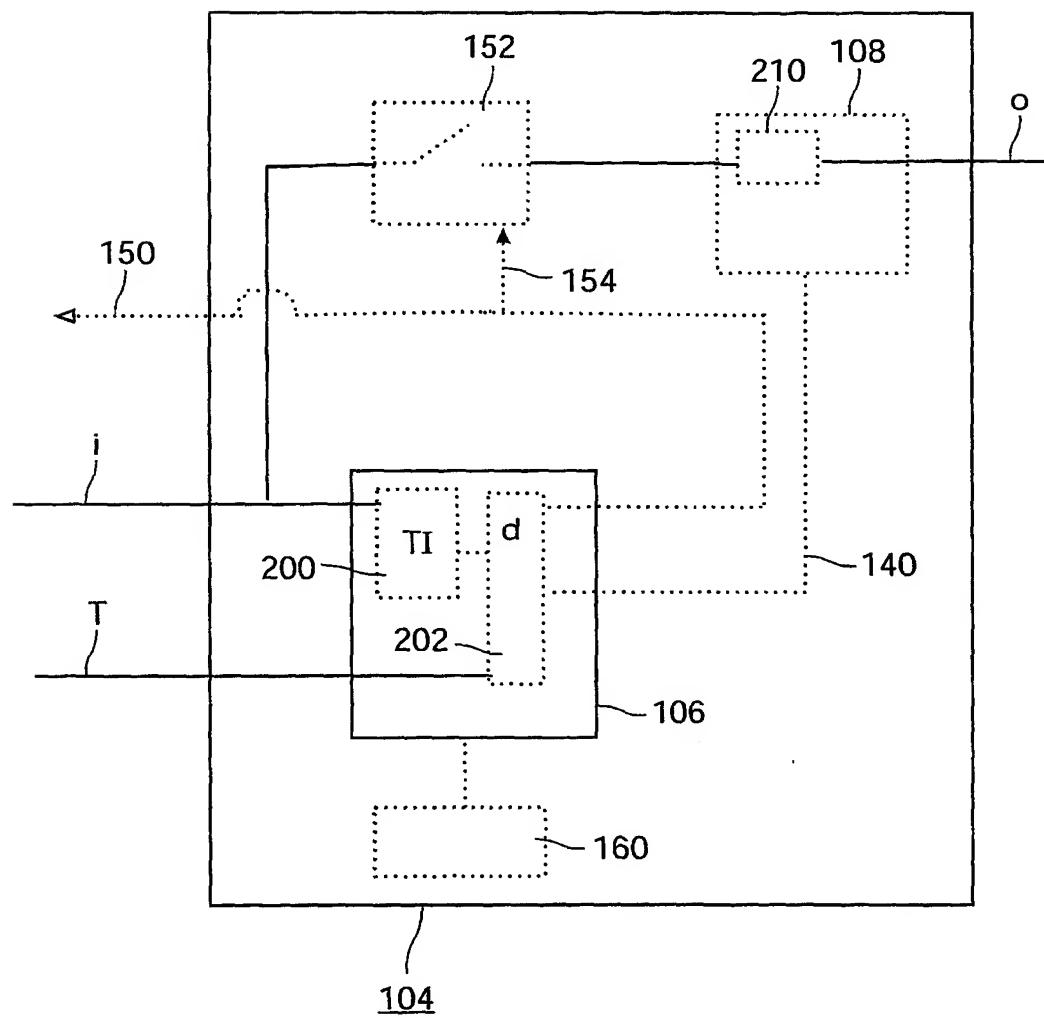
FIG.2
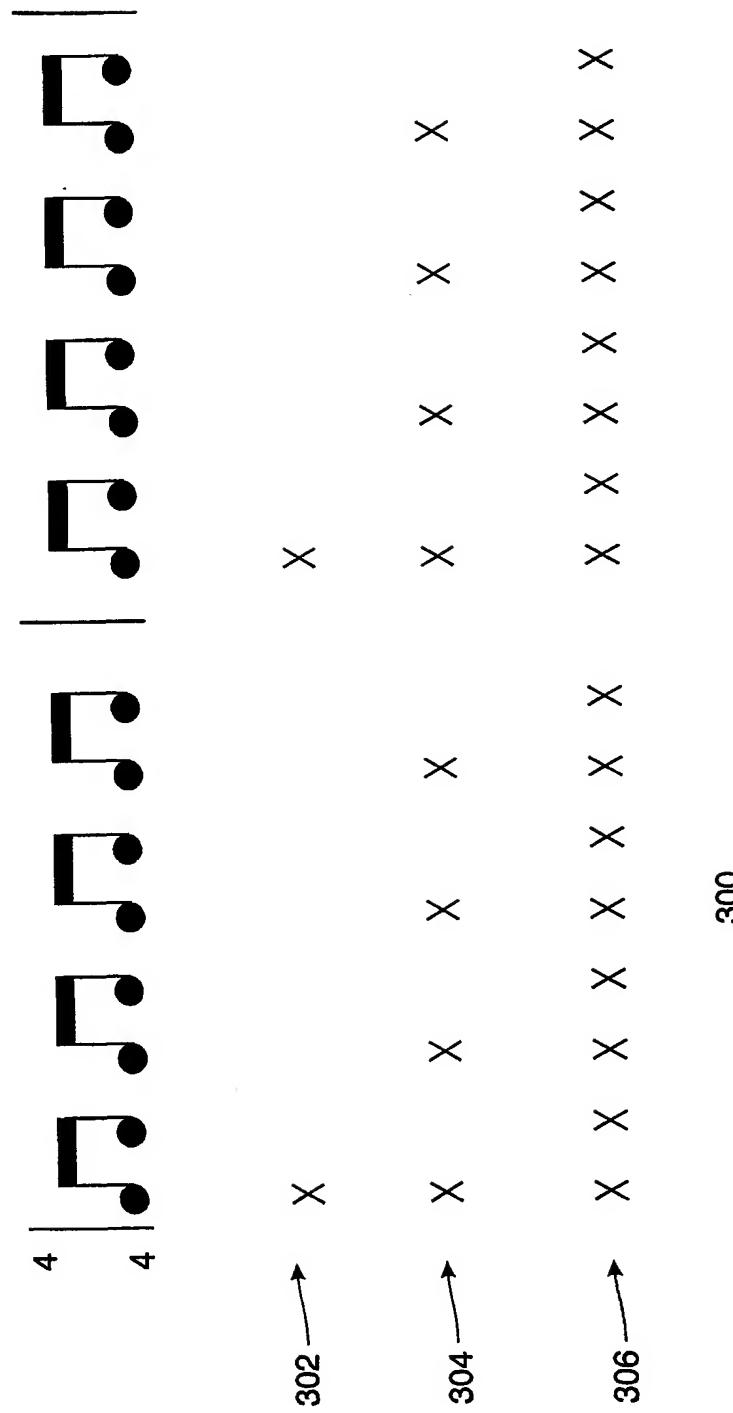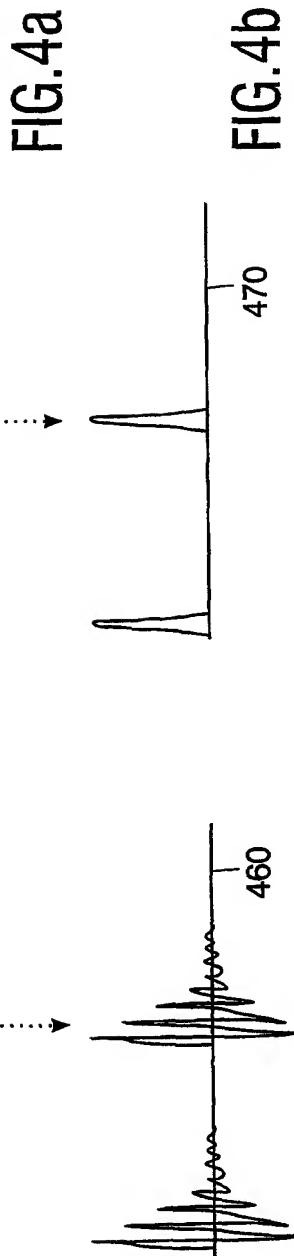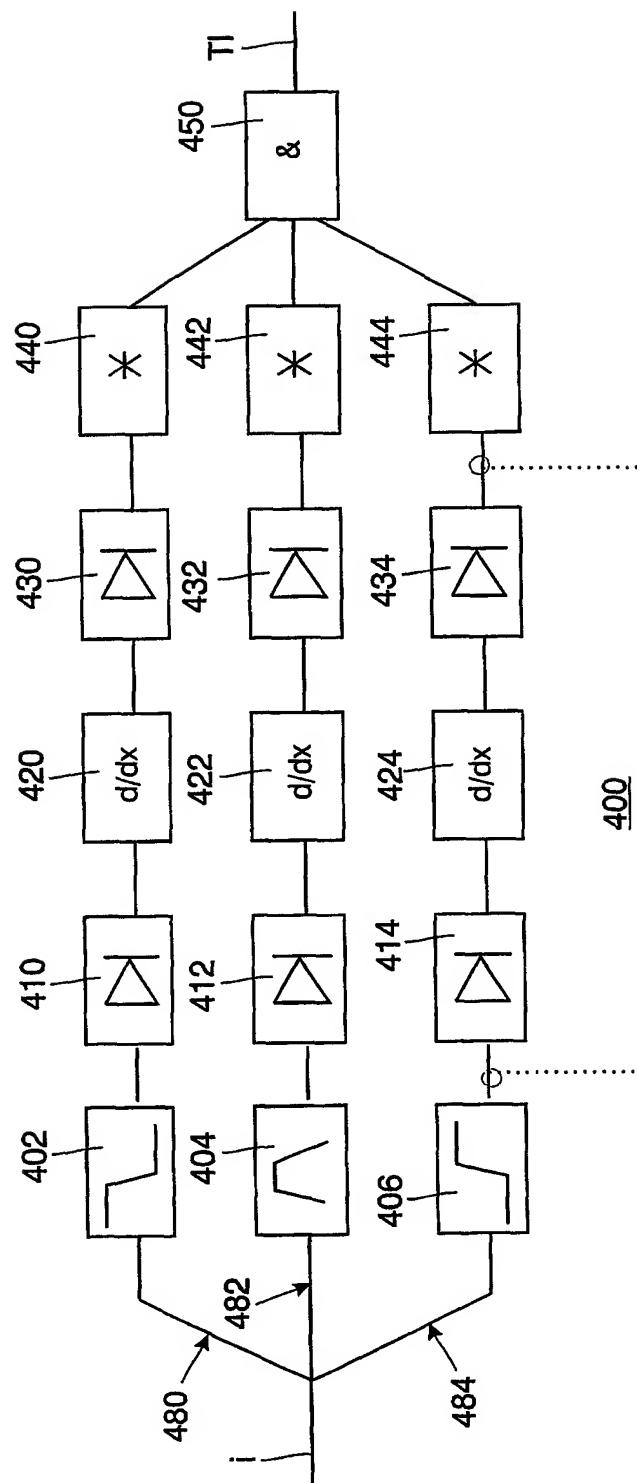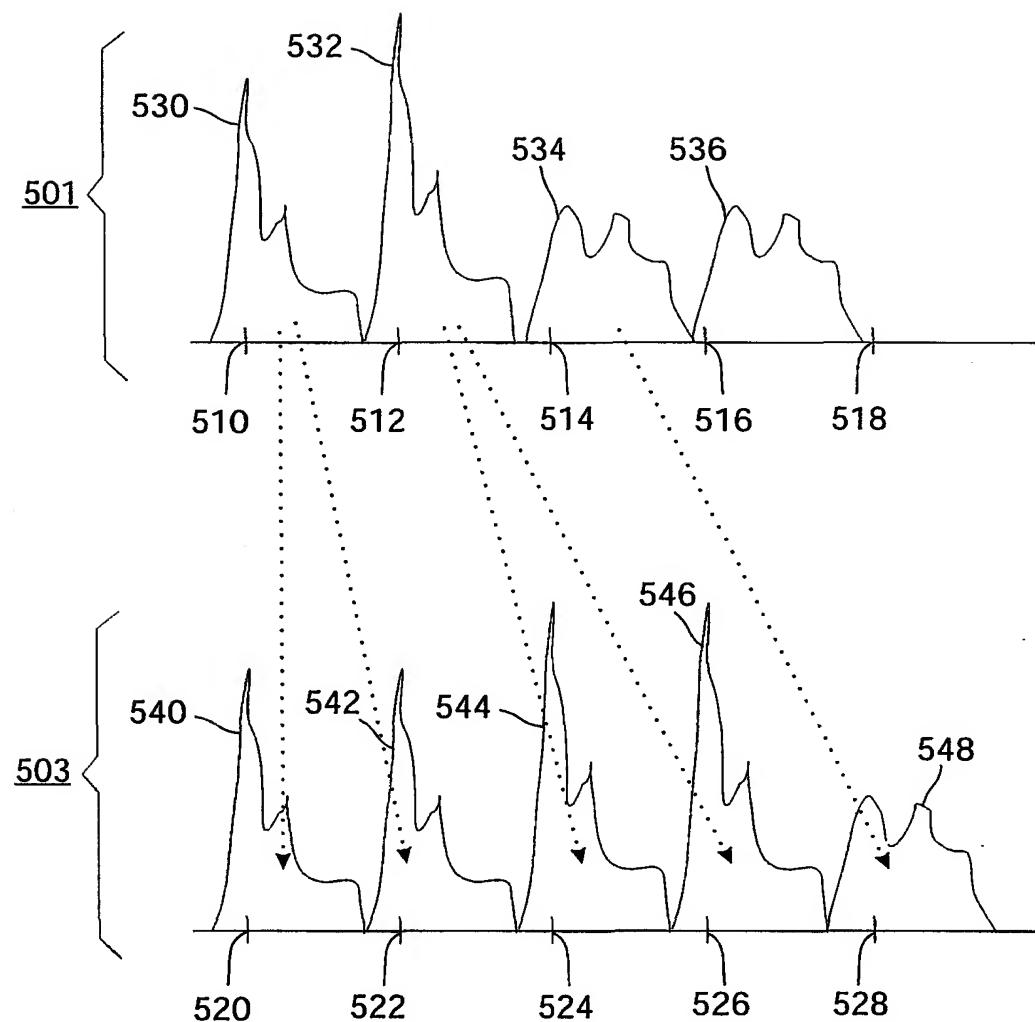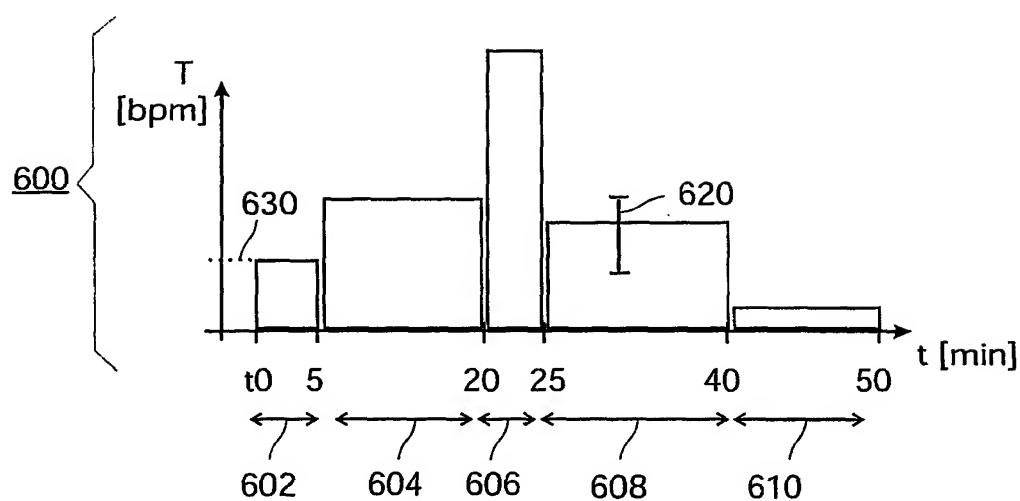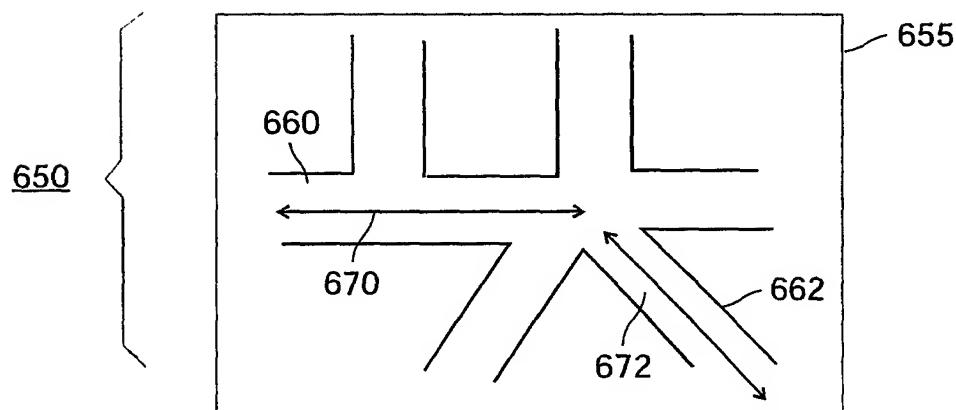
FIG.3

300

302

304

306

FIG.4a

FIG.4b

FIG.5

FIG.6a

FIG.6b

(51) International Patent Classification⁷: G10H 1/00

(21) International Application Number:
PCT/IB2004/050059

(22) International Filing Date: 28 January 2004 (28.01.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
03100307.2   12 February 2003 (12.02.2003)   EP

(71) Applicant (for all designated States except US): KONIN-KLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors; and

(75) Inventors/Applicants (for US only): MCKINNEY, Martin, F. [US/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). BREEBAART, Dirk, J. [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN DE PAR, Steven, L., J., D., E. [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN PAEPEGEM, Ludovic, A., J. [BE/BE]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: GROENENDAAL, Antonius, W., M.,; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(54) Title: AUDIO REPRODUCTION APPARATUS, METHOD, COMPUTER PROGRAM
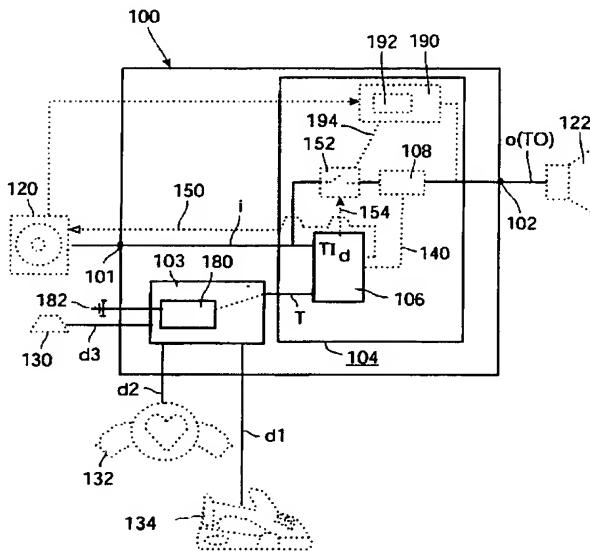
(57) Abstract: The audio reproduction apparatus (100) for sports training purposes comprises a tempo derivation unit (103) for deriving a selected tempo (T) on the basis of a data signal (d1, d2, d3) e.g. from a sports measurement device such as a heart rate meter; and an audio conditioning unit (104) arranged to deliver based on the input audio signal the output audio signal, with a tempo within a predefined accepted deviation from the selected tempo (T), whereby the audio conditioning unit (104) comprises a tempo calculation unit (106) arranged to calculate an input tempo (TI) of the input audio signal, and the audio conditioning unit (104) is arranged to deliver the output signal in dependence of the input tempo (TI).

Declaration under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

Published:

— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
14 October 2004

For two-letter codes and other abbreviations, refer to the "Guid-ance Notes on Codes and Abbreviations" appearing at the begin-ning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   G10H1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   G10H   G10L   A63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category°	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001 299980 A (MITSUBISHI ELECTRIC CORP) 30 October 2001 (2001-10-30)	1,7-9
Y	abstract & PATENT ABSTRACTS OF JAPAN vol. 2002, no. 02, 2 April 2002 (2002-04-02) & JP 2001 299980 A (MITSUBISHI ELECTRIC CORP), 30 October 2001 (2001-10-30) abstract & DATABASE WPI Derwent Publications Ltd., London, GB; AN 2002-031208 abstract	2-6
	-/--	

| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 July 2004	05/08/2004

| Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,
Fax: (+31–70) 340–3016 | Authorized officer

Lecointe, M |

4

Form PCT/ISA/210 (second sheet) (January 2004)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 251 441 A (GATEWAY INC) 23 October 2002 (2002-10-23) abstract paragraph '0006! paragraph '0018!	1,2
Y	WO 98/20482 A (CREATIVE TECH LTD ; LAROCHE JEAN (US)) 14 May 1998 (1998-05-14) abstract page 2, line 28 - page 3, line 10 page 5, line 18 - line 32 figure 3b figure 4	2-6
A	US 6 519 567 B1 (FUJII SHIGEKI) 11 February 2003 (2003-02-11) abstract column 1, line 43 - column 2, line 14; figures 5A-5F	2-6
A	SCHEIRER E D: "TEMPO AND BEAT ANALYSIS OF ACOUSTIC MUSICAL SIGNALS" JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA, AMERICAN INSTITUTE OF PHYSICS. NEW YORK, US, vol. 103, no. 1, January 1998 (1998-01), pages 588-601, XP008007174 ISSN: 0001-4966 cited in the application abstract	1,8,9
A	PICARD R W ET AL: "Affective wearables" WEARABLE COMPUTERS, 1997. DIGEST OF PAPERS., FIRST INTERNATIONAL SYMPOSIUM ON CAMBRIDGE, MA, USA 13-14 OCT. 1997, LOS ALAMITOS, CA, USA,IEEE COMPUT. SOC, US, 13 October 1997 (1997-10-13), pages 90-97, XP010251547 ISBN: 0-8186-8192-6 abstract page 91, column 2, line 16 - line 46 page 93 - page 94	1,2,8,9
A	US 5 137 501 A (MERTESDORF FRANK L) 11 August 1992 (1992-08-11) abstract; figure 2 claims 1-5 column 2, line 53 - line 68	1,8,9
A	US 5 215 468 A (LAUFFER DONALD K ET AL) 1 June 1993 (1993-06-01) abstract claims 1,2,4,8,12	1,8,9

4

INTERNATIONAL SEARCH REPORT

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
JP 2001299980	A	30-10-2001	NONE		
EP 1251441	A	23-10-2002	EP	1251441 A2	23-10-2002
			JP	2002373169 A	26-12-2002
WO 9820482	A	14-05-1998	US	6049766 A	11-04-2000
			WO	9820482 A1	14-05-1998
US 6519567	B1	11-02-2003	JP	3465628 B2	10-11-2003
			JP	2000322099 A	24-11-2000
US 5137501	A	11-08-1992	DE	3722468 A1	19-01-1989
			DE	3729691 A1	23-03-1989
			DE	3807241 A1	14-09-1989
			DE	3871957 D1	16-07-1992
			WO	8900064 A1	12-01-1989
			EP	0371042 A1	06-06-1990
			JP	2503996 T	22-11-1990
US 5215468	A	01-06-1993	NONE		

Form PCT/ISA/210 (patent family annex) (January 2004)